DOCUMENT RESUME

ED 239 854 SE 043 765

TITLE Microelectronics in the Curriculum--The Science Teacher's Contribution.
INSTITUTION Association for Science Education, Cambridge (England).
PUB DATE Mar 82
NOTE 14p.; Prepared by the Microelectronics and Science Education Sub-Committee.
AVAILABLE FROM Association for Science Education, College Lane, Hatfield, Herts, AL 109AA England.
PUB TYPE Reports - Descriptive (141)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Computer Science; *Course Content; *Curriculum Development; Educational Objectives; Science Education; Secondary Education; *Secondary School Science; Systems Approach
IDENTIFIERS Association For Science Education; *Great Britain; *Microelectronics

ABSTRACT

Rapid advances in microelectronics over the past few years have generally been beneficial, but they have also created some problems, and questions must be asked about the philosophy for including aspects of the new technology in the school curriculum. This statement, prepared by the Microelectronics and Science Education Subcommittee of the Association for Science Education (ASE) and centered on the belief that all students should be introduced to the subject, is intended to serve as a stimulus for discussing the many educational, vocational, and social issues raised by rapid advances in the field. The statement is in three parts under the headings of (1) the new technology within the school curriculum; (2) microelectronics within the science curriculum; and (3) microelectronics: role of the ASE. The first part considers the importance of microelectronics, microelectronics topics, the need to reach all students, implementing microelectronics into curricula, and provisions for specialist courses and children with high quality characteristics. The second part focuses on the role of science and related departments, microelectronics topics in science, "components" versus the "systems" approach, diversity within schools, and suggestions for discussion. The final part considers the role and importance of the ASE in implementing microelectronics courses and programs. Each part concludes with a list of recommendations. (JN)

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MICROELECTRONICS IN THE CURRICULUM

- THE SCIENCE TEACHER'S CONTRIBUTION

A Statement prepared by the Microelectronics and Science Education Sub-committee of the Association for Science Education

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C O N T E N T S

A. The 'New Technology' within the School Curriculum

B. Microelectronics within the School Curriculum

C. Microelectronics - the Role of the ASE

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F O R E W O R D

Rapid advances in the field of microelectronics over the past few years have generally been beneficial, but they have also created some problems, and questions must be asked about the philosophy for including aspects of the new technology in the school curriculum. When considering questions about the best approach to the subject and appropriate content matter, it must be borne in mind that not only will some pupils benefit from directly vocational aspects of the subject, but also that all pupils must be provided with background knowledge which will help them to make informed decisions as citizens of the future.

This statement is intended to act as a stimulus to discussion of these issues by all teachers. It is hoped that a wide audience will read and act upon this statement, so that schools are not accused of ignoring present developments in microtechnology.

I would wish to commend the statement to a wide number of readers, and to express the Association's thanks to Doug Masterton and his committee for all the time and effort they have devoted to its production.

M.J. Savory
Association Chairman

March, 1982.

The following are members of the Association's Microelectronics and Science Education Sub-committee.

Mr. R.D. Masterton (Chairman)
General Adviser, Leeds Education Authority

Mr. P.E. Dutton, Director, the Sheffield Region
Centre for Science and Technology

Mr. K.A. Shaw, Department of Education,
Sheffield Polytechnic.

Dr. J.F. Hewitson, Oundle School

Mr. N. Rowbotham, Loughborough Grammar School

Dr. R.S. Watson, Computing Technology Unit,
National Physical Laboratory

Mr. J. Turnbull, National Computing Centre

Mr. R.A. Beare, Department of Science Education,
University of Warwick

Mr. A.R. Walwyn, Malvern College

Mr. B.R. Harris, H.M.I.

Mr. B. Samways, Educational Computing Centre,
Birmingham

March, 1982

MICROELECTRONICS IN THE CURRICULUM

- THE SCIENCE TEACHER'S CONTRIBUTION

A. THE NEW TECHNOLOGY WITHIN THE SCHOOL CURRICULUM

1. Its importance

Few people in the United Kingdom can be ignorant of all the predictions being made about the effect of microelectronics on our individual or national way of life. The development of microelectronics technology has been well described by many commentators. Devices which only a few years ago would have cost large sums of money are now obtainable very cheaply. The technology is being applied not only to improve existing products, but also to create hitherto unimagined devices and applications.

It is now possible for cheap high speed microcircuits to carry out almost any control or computational task. The number of consumer items available and containing these devices shows this well, but consumer goods are not the whole story. In commerce, manufacturing and education, many skilled operations, which formerly could be carried out only by people, can now be performed by machinery under electronic control.

This ubiquity of microelectronics leads inevitably to the question of whether or not aspects of the technology ought to be taught within the school curriculum, but the question is widened in scope by the effect these developments are having on employment opportunities. Commentators have listed many jobs that are at risk from the application of microelectronics technology, and it is significant that they are not confined to any one social or occupational group. Some 15% or more of existing jobs may become superfluous, and this figure does not include jobs lost as a result of the current recession. Some commentators foresee factories completely unmanned, or people working from home at a computer terminal. Quite apart from such novel concepts, it is clear that microelectronics will continue to cause changes in patterns of working and in the jobs themselves, and the new technology will create jobs at present unimagined. The advent of the motor car created many employment opportunities for people who might otherwise have been rearing horses; microelectronics may yield a late twentieth century parallel. Apart from the directly vocational aspects for children leaving school, the subject has a wider educational importance. For years to come there will be national debate on such matters as the sharing of work, the distribution of wealth, compulsory periods of education, etc., resulting in political decision-making. Schools must make their contribution to the ideal of the informed electorate by providing future citizens with background knowledge of the issues that will concern them.

2. A list of topics

By publishing this document called "Microelectronics in the Curriculum" ("Information Technology" would be an alternative title), the Association aims to promote discussion centred on its belief that all pupils should be introduced to the subject of microelectronics. This introduction should provide a general awareness of the subject, not only as a basis for more specialised studies, but also to give an insight into some of the ways in which the technology may develop. In the latter case, the following topics may be appropriate.

(i) Information storage, retrieval and transmission.

(ii) Communicating with machines: the concept of a computer.

(iii) Programmability and control.

(iv) Word processing and data processing.

(v) Applications of microelectronics and machine intelligence.

(vi) Social consequences of microelectronics, privacy, security, fraud, etc.

(vii) The cashless society.

(viii) Ethical and moral questions:- job replacement, worksharing, wealth distribution, etc.

Such a list draws attention to the fact that microelectronics does not as a subject fit completely into any existing area of the school curriculum. Nevertheless, the Association has discussed this and proposes that during their compulsory years of schooling all pupils should be introduced to aspects of microelectronics such as the examples listed above. It is not envisaged that pupils will emerge from school accepting uncritically all the consequences of progress in microelectronics. On the contrary, it is hoped that they will be sufficiently familiar with the technology for them to be able to assess its function within the vision of society they may hold, and to be helped by it to find their roles as creative human beings within that society. Unless the public have some background familiarity with microelectronics technology, political decisions swayed by the populist tools of rumour, hearsay and prejudice may be made about it. The direct social impact of microelectronics may very well be greater than that of the use of nuclear fission for the generation of electricity; it would be regrettable to have a repetition on a similar scale of the present public ignorance.

3. The need to reach all children

Many secondary schools, often displaying considerable initiative, have acquired microcomputer systems. Sometimes this has been achieved with the help of parents, or with a subsidy from funds available elsewhere. An increasing number of primary and middle schools also have microcomputers and it is evident from the enthusiasm of pupils that quite young children can understand some of the functions of microcomputers and indeed some simple programming. Schools acquiring such machines find that some of the programs are of value educationally and are confident that further useful materials will follow. However, some of the aspects listed in Section 2 are clearly abstract and it would be quite unrealistic to assume that all of them could be taught to children in the early secondary stage. Children cannot be expected to see our culture as a whole unless complementary studies in mathematics, science, history, geography and religious education as well as microcomputing have reached a suitable level. Some teachers may feel that this cannot be achieved until the later secondary stage. While specialist teaching of microelectronics and computing to the levels required by the various Certificates is of considerable importance for the needs of future engineers, technicians, scientists, managers and computer personnel, it does not remove the need for general education in microelectronics to be given to children of all ages, abilities and interests. The Association believes that this should be provided for as many children as possible during the secondary stage. An important educational element should not be inaccessible to large numbers of children. In particular, it should not be limited to special groups or to those who remain at school after the years of compulsory schooling.

4. How it might be organised

In recent years the school curriculum has come under considerable pressure, usually to expand in scope, and one way of responding has often been to include new subjects within an options scheme. Lately people have questioned reliance on options for the greater part of the secondary school curriculum and have realised that to add one class in a subject such as microelectronics to an already long list does not give a majority of the children experience of that subject. The Association does not propose the apparent alternative, that microelectronics should become a compulsory subject, for even if staff and equipment were available, such a change would distort an already overstretched curriculum. Microelectronics can, however, be introduced into an existing curriculum within the general subjects already taught if the various heads of departments in a school are willing to cooperate creatively with other departments, to allow the introduction of cross-disciplinary topics, and generally to permit their subjects to contribute to the general education of the children as well as to their specialist education.

It can be argued that a member of the school staff should be given the job of 'microelectronics coordinator'. Ideally, this teacher would have attended a suitable training course providing awareness of microelectronics and its educational implications. He or she would be able to compile a list of themes or topics appropriate for inclusion within the curriculum of the school. Through discussion with individual heads of departments, the 'coordinator' would modify schemes of work and provide suitable teaching resources for other teachers to use. The coordinator would also act as an adviser within the school for colleagues wishing to use electronic aids and computers within their own programmes of work. He or she need not necessarily be a science teacher, but would need to be confident of receiving resources, cooperation and encouragement from all departments.

5. Provision of specialist courses and children of high ability

The Association does not wish to neglect the teaching of specific high level skills. Not all children studying to O/A Level or O/H Grade standards may do so in subjects such as Computer Studies, Electronics or Electronics Systems, and some schools attempting such courses are not equipped to do so. The opportunity to study such subjects should be open to all children of high ability so that key industries, commerce and research are not deprived of suitably qualified clever young people with the creative flair so important to us as a nation.

Children with skill in electronics and computing may find it easier to get jobs, and industry needs employees having some acquaintance with modern production methods based on microelectronics. Ways must be found by which children who would benefit from specialist courses may follow them, regardless of difficulties caused by falling rolls, limited finances and shortages of key staff. Local solutions may be possible involving specialist teachers working in more than one school, shared facilities, distance-learning methods and the retraining of teachers.

6. Recommendations

(i) The secondary school curriculum should include some microelectronics awareness for all pupils.

(ii) Advanced aspects of microelectronics awareness should be introduced within the period of compulsory schooling whenever children possess the intellectual maturity to appreciate the concepts involved.

(iii) A teacher in each secondary school should be designated to take responsibility for microelectronics coordination, to introduce work across subject boundaries and to coordinate progress.

(iv) All school subject departments should reappraise their schemes of work from time to time, in consultation with the microelectronics coordinator, to make sure that these meet the needs of the children currently in the school. At such times it may well be possible to introduce microelectronics-related content on the lines suggested in Section 4.

(v) School science departments should make a specific contribution to the task of introducing children and staff to aspects of microelectronics.

(vi) More facilities for the teaching of electronics, microelectronics and computing should be provided so that in all schools children who are able to benefit from specialist courses have the opportunity to do so. Schemes which at present assist schools without equipment to purchase one microcomputer should be extended to:-

(a) all primary schools, secondary schools, special schools and further education colleges where staff have received appropriate training;

(b) support the purchase of computers up to a level of at least one for each hundred pupils/students.

(vii) Schools should provide as many opportunities as possible for children to use electronic equipment in addition to formal courses in microelectronics awareness. This may be possible through:-

(a) the use of relevant material for computer assisted learning;

(b) encouraging hobby club activities outside formal lesson hours;

(c) the loan of equipment to pupils for short periods;

(d) the provision of voluntary classes for pupils wishing the pursue topics in greater depth.

B. MICROELECTRONICS WITHIN THE SCIENCE CURRICULUM

7. The role of science departments and others

The science department should not be the only department concerned with fostering microelectronics awareness. There are indeed strong links between science and microelectronics, but there are equally close links between microelectronics, computing and mathematics. In many schools it is the mathematics department which has introduced computing either as a specialist course or as an awareness element within existing syllabuses. Social aspects may be the province of the humanities and other subjects may use or make reference to the techniques - for example, home economics (electronics control) or art and design (electronics- assisted photography, computer-aided design). In whatever way the school responds, coordination is important to ensure a systematic presentation of ideas to the children, to eliminate duplicated endeavour and to avoid important omissions.

There are close links between microelectronics and science education:-

(i) Introductory electronics is an extension of general work on electricity and circuits, an important part of all science courses.

(ii) A practical study of microelectronics uses concepts and apparatus from other branches of science teaching.

(iii) Electronics devices can assist science teaching at least as much as they do other subject areas.

(iv) The applications of scientific principles and of microelectronics within industry can often be discussed in the same context.

(v) Those seeking a career in electronics or computers often need qualifications in science subjects.

(vi) Science teachers educated in recent years are more likely than other groups of teachers to have had contact with the new technology.

8. Topics in science

The science department has a particularly important role to play in the teaching of microelectronics awareness and in supporting the efforts of other subject departments, and it would be wrong for the department not to do so. What it can do depends both on the nature and circumstances of the department within a given school, and also on ideas supplied by groups of teachers. Further discussion and trials will be needed before there can be general agreement on its role. The list which follows gives some of the more obvious topics but it is not definitive, nor could all the topics on the list be taught. However, it does show how important the practical and other expertise of the science department may be, particularly if the pupil wishes to know how some of the devices function. The science contribution should not be confined to the practical/components level, though this is important, and some of the possibilities are exciting.

(i) The physics solid state devices.

(ii) The transmission of information by electronic devices.

(iii) Methods of electrical switching and control.

(iv) The construction and operation of digital and analogue circuits.

(v) Methods of manufacture of microelectronics circuits.

(vi) Electrical information sensing.

(vii) Electrical feedback.

(viii) Purchase and construction of devices using microelectronics.

There may be an overlap with work appropriate to other subjects such as mathematics, computing, craft, design or technology, though applications of microelectronics are not only very much a part of science but also an enjoyable part of it.

9. The "Components" versus the "Systems" approach

In broad terms there are two approaches to the non-vocational teaching of electronics (including microelectronics) at school level.

One is to consider how the components work, to explain the relationships between the variables, to define the parameters for the components and to devise

and perform experiments to measure those parameters and/or to demonstrate the relationships. For example, passive components such as resistors and capacitors and active components such as diodes and transistors can be explained in this manner, at different levels of sophistication according to the age and ability of the pupils and students. It is perfectly possible to extend this approach to explain how circuits work, especially at higher levels, though few students whilst at school will need to have the detailed mathematical explanation of how the more complicated devices actually work.

The other general approach is to accept the ways in which components may be put together to produce a given effect and to use that effect to solve a problem. For example, a collection of diodes and resistors can form a 'gate' which performs a given logical function. An 'AND' gate will give an output voltage or signal only when all the inputs receive a voltage or signal, whilst an 'OR' gate will given an output when any one (or more) of the inputs receive(s) a signal. Similarly, the 'black box' may be an amplifier, microprocessor, memory device, input/output buffer, analogue-to-digital (or vice versa) converter, and so on. This approach has been shown to be educationally viable and to work in practice for pupils or students of all ages and of most abilities.

10. The diversity within schools

Studies by Her Majesty's Inspectorate reveal that many different science subjects are taught in schools : in the last two years of compulsory schooling there is no "common denominator" in the science curriculum. Science departments themselves are organised in many different ways. Even if it were desirable, it would not be possible to decree that microelectronics should be incorporated into physics (say) and believe that the problem was then solved. If education in science were to be provided in a more uniform way throughout secondary education, new topics could be more easily included. However, reform is likely to be slow and to depend on the outcome of curriculum developments in the field of 'Science for All'.

It is the view of this Association that a microelectronics element should appear within existing science courses as soon as possible and that some developments need not await more general curriculum reform.

11. Suggestions for discussion

A microelectronics element could be introduced within present courses in several ways and the following suggestions are offered for discussion. If implemented, they would not succeed in exposing every child to this topic, but should reach many.

(i) A microelectronics element should be incorporated into the following syllabuses at O-level, O-grade, CSE, 16+, General and Credit levels:-

Physics)
Physical Science) and other subjects covering similar ground.
Technical Science)
General Science)

(ii) Relevant examples of the use of microelectronics devices should appear in all science courses.

(iii) Wherever possible, instrumentation incorporating microelectronics devices should be encouraged, provided that this does not diminish basic understanding of the principles being measured. Such devices will be used during work and during leisure in the years to come : science teachers should accept them too.

This suggestion implies the natural use of calculators, small computers and electronic information retrieval systems as well as specialised apparatus such as digital meters and data capture devices.

(iv) Science departments should be encouraged to make creative use of computers in their work, for Computer-Assisted Instruction (CAI), for Computer-Managed Learning (CML), for control/logging of long experiments and for administration. A microcomputer could be as natural a feature of a school science laboratory as a top-pan balance - or as common as a TV receiver.

(v) Staff should be given the opportunity to attend in-service courses so that they can become familiar with microelectronics. Such courses should not be limited to those staff already directly involved in teaching microelectronics.

Direct teaching is only one of the ways by which children can gain experience of microelectronics. In industry and commerce, computers and microelectronics devices are used solely because this leads to greater efficiency and profitability. In a school, a student using a computer programmed to teach a topic in chemistry (say) will, as a by-product, gain confidence and familiarity with the equipment.

Systems can be designed for Computer-Managed Learning (CML), Computer-Assisted Instruction (CAI) and computerised administration. The people who use them may undergo subtle changes in attitude towards microelectronics technology. This is not a justification for the uncritical use of electronics devices and computers, but microelectronics awareness is a useful side effect.

Science teachers have been active in suggesting what use can be made of computer resources and science is at least as well provided for as other regions of the curriculum. Systems for CML have been tried, notably for A-level Physics. Enthusiasts for CML claim that a student's progress is more carefully monitored than through conventional teaching methods, that CML can help in the problem of teaching some subjects to small and otherwise uneconomic groups, and that it may in the long term have an effect on theories of teaching method. Science teaching may also be affected by information retrieval systems and devices such as British Telecom's "Prestel".

A balance should evolve between teaching about microelectronics technology itself and the use of it as an aid to teaching other topics. The two approaches are complementary and each requires appropriate provision of resources. One microcomputer in a school cannot do more than focus the attention of staff and students on the problem. Teaching materials and in-service training will clearly need funding in some way, and in particular local authorities, governing bodies, etc., should assume that science departments will make use of such improved facilities. Indeed, some science departments are already acquiring a departmental computer.

12. Recommendations

(i) School science departments should involve themselves actively in an appraisal of microelectronics within the whole curriculum of a school. They should provide as much help as possible to non-scientist colleagues. The microelectronics element within science should be seen as part of a more general awareness of the subject to be included in the curriculum for all children.

(ii) External examination syllabuses in science subjects should be revised to include, where appropriate, a microelectronics

element. (In the resultant pruning, material supportive to this element should not be deleted from syllabuses.)

(iii) Microelectronics should be included in the syllabuses being developed for the Common Examination System at 16+ and those for Foundation, General and Credit levels.

(iv) Science teachers must consider how to include microelectronics in their teaching so that pupils and students may use the devices when solving problems appropriate to their age and ability. This may be in normal laboratory classes or as part of design or other projects, whether within physics courses or courses on electronics, computer studies or technology.

(v) Manufacturers of apparatus should be encouraged to design suitable simple materials for the teaching of microelectronics concepts at the secondary stage.

(vi) Government funding should be made available to suitable agencies for the development of syllabuses, apparatus and teaching resources produced in a format within the financial grasp of schools.

(vii) Government funding should be made available to suitable agencies for the development of computer-assisted learning, computer-managed learning and computer-assisted administration wherever relevant to science teaching, both within and without the secondary sector.

(viii) Local authorities should provide opportunities for in-service training, to introduce science teachers to microelectronics or related areas. The scale of provision should allow the majority of serving teachers to attend a suitable course within the next five years. Head teachers should be encouraged to see that the personal development of science staff includes familiarisation with microelectronics.

(ix) Schools should be given such extra financial resources as are necessary to make it possible for them to teach some microelectronics through class practical work to all pupils.

(x) Local authorities, governing bodies or other agencies responsible for the maintenance of schools, should see the purchase of microcomputers by schools as a high priority and should assume in particular that science departments will make use of them.

C. THE ROLE OF THE ASSOCIATION FOR SCIENCE EDUCATION

13. Agencies

Through its journals, meetings and conferences, the ASE has been able to provide a valuable means of helping science teachers to keep up to date and to be informed of new developments in science teaching. Members will expect the Association to meet their need for increasing their knowledge of microelectronics and computing. If microelectronics is ultimately taught in a cross-disciplinary fashion, not all the teachers involved will have such easy contact with the publications and meetings of the Association. Other agencies concerned with helping teachers in this area include Microcomputer Users in Secondary Education (MUSE), the Computer Education Group (CEG), the Schools Committee of the British Computer Society (BCS) and the Regional Information Centres of the Microprocessors in Education Programme.

There are several journals and publications which deal specifically with education and computing, such as the CEG journal "Computer Education" and the magazines "Educational Computing" and "Microcomputers in Schools" (the journal of MUSE). Clearly it would be foolish for the Association to duplicate the work of other agencies.

14. The importance of the ASE

Most of the contributions to the Association's journals about microelectronics and computing are likely to relate to the teaching of science. It would be unfortunate, however, if the general educational scene were to be ignored and if science teachers were to be unaware of the developments and discussions involving other subjects. It is particularly important that the Association should encourage links with other subject associations and involve them, where appropriate, in curriculum developments initiated by the Association.

Of particular importance is the ASE/Schools Council Review of the Secondary Science Curriculum, the main science curriculum development in the 1981 - 1986 period. Any national science project should make suggestions both about the use of microelectronics devices and computers and about fostering a general awareness of these. Any curriculum development in (say) computer-assisted learning in science should be related to what is proposed for science education as a whole.

15. The Microelectronics and Science Education Sub-committee

The general awakening of interest in microelectronics led the Association to set up the 'Microelectronics and Science Education' Sub-committee. This group has sought to help members keep abreast of developments, through symposia, etc., at the Annual Meeting. It has helped the Association's Officers respond to Government initiatives. It has kept in touch with the Computer Education Group, the Schools Committee of the British Computer Society, and most of the developments in education and elsewhere. To do all this and to have a strong contribution from classroom teachers without becoming too large a group has not proved easy.

16. Recommendations

(i) Members of the Association should be encouraged to publish and exchange ideas on microelectronics and computing in science education by way of the Association's journals. Authors will need advice and help from editorial staff so that useful original ideas do get into print. A special section of "The School Science Review", a newsletter or a Study Series publication may be required if enough contributions appear.

(ii) Publications and articles produced by other subject associations, professional institutions and the press in the field of microelectronics should be kept under review, and if appropriate should be drawn to the attention of members through the notes and review columns of the journals, or even by reprinting certain articles.

(iii) Formal links should be established between the ASE/SC Review of the Secondary Science Curriculum and other agencies developing materials for computer-assisted learning in science or methods for teaching microelectronics.

(iv) When the Advisory Committee of the Association proposed in "Education through Science" is set up, it should include representatives involved with education in computing and microelectronics.

(v) At an appropriate time one of the Association's Secretaries should be given sufficient training to enable microelectronics and related curriculum developments to become his or her special concern.

(vi) The role and composition of the 'Microelectronics and Science Education' Sub-committee should be kept under continuous review by the Education (Co-ordinating) Committee, to ensure that it helps the Association to be well informed of all developments in the field of education in microelectronics and the applications of microelectronics for science teaching.

(vii) When the Association considers publishing materials specifically concerned with microelectronics, the language, layout and publicity should be suited to the needs of non-scientists working in microelectronics as well as to the needs of scientists.

(viii) The Association should inform other subject associations of the assistance it can offer in considering the implications of microelectronics for their subject, including possible changes in curriculum content, resources and procedures for implementation.

(ix) Any development of apparatus specifically designed for teaching microelectronics and computing within the science curriculum should involve the Apparatus Sub-committee of the Association.

March, 1982.